A HAND BOOK FOR TEACHERS OF CHEMISTRY

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A HAND-BOOK FOR
TEACHERS OF CHEMISTRY
IN
SECONDARY SCHOOLS

BY

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PREFACE.

THIS little book has been prepared for the use of teachers of Chemistry in our secondary schools, in the hope that it may be helpful in presenting a difficult subject. It is a cause for regret that many teachers are obliged to give instruction in Chemistry with very limited apparatus, and, what is even worse, to perform experiments in laboratories which are not properly equipped with draft cupboards. To add to these difficulties, text-books often give very imperfect directions for performing many important experiments, and if those experiments are attempted by large classes, as directed in the text-books, they become a source of danger to the health of both students and teachers. This is particularly the case in studying the properties of gases. We cannot hope for a remedy for this state of affairs until we have more stringent school regulations in regard to general health, as school boards are very often unwilling to supply even the most necessary, to say nothing of efficient, appliances for teaching the subject. It is to aid in overcoming these difficulties by means of inexpensive apparatus, that these hints and suggestions are submitted for the consideration of Science teachers.

The methods employed, and the experiments and modifica-

tions of experiments, are for the most part original. The introduction to the chemical equation is based on the recommendation of one of our foremost teachers of Chemistry, that in teaching the science the principles should be introduced as early as possible. But the plan of teaching the equation, and the method of handling noxious gases in the laboratory by large classes, and the method of gas analysis, are entirely new. This is also true of the modifications of experiments, except where otherwise stated. It might be added, however, that the plan of handling noxious gases is based on a method which is sometimes used in qualitative analysis. All except two of the experiments to illustrate the Law of Definite Proportions, and many of the suggestions in the chapter of General Hints, are collected from various sources. The section on Graphic Formulæ is taken from Bailey's "Tutorial Chemistry."

I may not have presented the best way of performing these experiments in every case, but if this little book proves helpful to any of my fellow-teachers in overcoming their difficulties, or if it should induce others to present their plans of work for the consideration of their fellow-teachers, I will feel amply repaid for the time spent in working out the details of the methods and of the experiments which have proved so successful in my own classes.

ST. CATHARINES, J. A. GIFFIN.

October 4th, 1900.

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A HAND-BOOK OF CHEMISTRY.

CHAPTER I.

THE CHEMICAL EQUATION: HOW TO TEACH IT.

§ 1. Introductory Work.

A teacher of Elementary Chemistry finds many difficulties in his work, and one of the greatest he encounters is in teaching junior students to write a chemical equation, and to have a proper understanding of what it denotes. The reason for this is quite apparent. To successfully express a chemical fact it is necessary to have a comprehensive idea of the theory of the constitution of matter, without which a beginner will not make much progress in his work.

Among the many plans suggested for teaching equations, by writers of text-books, none are satisfactory. The introductory work is not always arranged in logical order, nor with a view to giving the student a clear conception of the atomic theory. Many points are omitted which give considerable trouble, and the teacher is left to work out his own plan to overcome these difficulties. It may be argued that this is not within the province of an elementary text-book, but surely anything which will aid the student in getting a better grasp of the subject should have a place in such a work.

One important reason why the beginner has so much diffi-

culty in writing an equation is because he does not use the gift of imagination, nor does the teacher always encourage him in its use. By imagination is not meant mere fancy, which creates unreal and impossible images, but the power of making pictures to the mind of that which exists, though it is invisible to us. It is well known, for example, that oxygen and hydrogen combine to form water, and that this may be expressed by an equation. But it is better still to have a mental picture of the atoms clasping each other, and combining so as to form a new substance, and to feel how wonderful are the forces which bring about such a change. "No one loves dry facts; we must clothe them with real meaning and love the truths they tell, if we wish to enjoy science." If we as teachers fail in using this gift, it is not astonishing that our students look upon chemistry as drudgery, and study it because they find it necessary to pass some examination, and not because they enjoy learning more about nature and discovering its secrets.

Another reason is that inaccuracies occur in some text-books, which lead to misconceptions, and many important facts which aid in explaining the atomic theory are not introduced until the student has almost completed his study of inorganic chemistry. He learns early that two or more elements may combine to form a number of different compounds, but is not given a rational reason why one compound should be formed rather than another, and facts are not placed before him which will enable him to predict what may take place when he performs an experiment, or to confirm his results after he has done his work. Sometimes statements are made which have long been discarded by chemists, and the beginner is asked to learn many things which might be much better acquired by introducing facts in harmony with the most modern discoveries. For example,

the old method of classifying the elements into monads, diads, triads, etc., has been retained in some text-books, so that the students may be enabled to write the compounds of the elements. It is worth while asking if this is not only unnecessary but misleading. Would it not be one hundred times better to give the same information by means of Mendelejeff's classification? Why should we leave the introduction of such an important law until we have studied the more important elements and their compounds? From the table the formulæ of the different oxides may be seen at a glance, and then how easy it is to write the sulphides, sulphates and carbonates. The classification further indicates the way in which the other elements combine with hydrogen, and when we know how hydrogen combines with oxygen, it is not difficult to determine how many atoms of hydrogen the metals displace in the hydrogen compounds, and how the metals and metalloids form their chlorides, bromides, hydrates, nitrates, etc. Thus we have a simple and rational method of writing out the more important compounds of the elements, and at the same time we may draw attention to many other features of one of the greatest discoveries of chemical science.

It has long been the opinion of the best teachers of Chemistry that the principles underlying the subject should be introduced as early as possible. For that reason, in the plan here submitted, the Law of Constants, the Law of Definite Proportions, the Law of Multiple Proportions, some features of the Periodic Law and Avogadro's Law have been introduced at the very beginning of the work, and in practice the result has been exceedingly satisfactory. Experience has shown that in carrying out this or any other plan, the aim should be to give the student experimentally, and as quickly as possible, a comprehensive notion of the atomic theory. In so doing, care should be taken not to make use of experi-

ments which would be confusing, or which would become burden to the memory. Hence the beginner should perform or see performed, only such experiments as would have som practical value in illustrating the principles underlying th subject.

In the suggestions that follow, it has been assumed tha the student has a knowledge of elementary physics, or in other words, is familiar with the physical properties of liquids and gases, and hence that he has acquired some facts which would aid in introducing the atomic theory.

First, by means of experiments, the beginner should obtain a knowledge of a physical change, a chemical change, the conditions that promote a chemical change, and the difference between a mixture and a compound, etc. Attention might also be drawn to the great number and variety of chemical compounds. Then the question naturally arises, are the substances which enter into a combination themselves compounds? This introduces the elements, their number, their symbols and what the symbols denote, the fact that the elements have not been decomposed, and that they may be divided, in a general way, into metals and non-metals; and further, it brings up the important question, how do elements combine to form compounds? Such a question may most easily be answered by the analysis and synthesis of water, or the analysis and synthesis of hydrochloric acid. In these experiments the student sees that the gases oxygen and hydrogen, and hydrogen and chlorine, unite in definite proportions by volume, and that they must of necessity unite in definite proportions by weight. Then, very naturally, come the important questions, Are compounds constant in composition, and is it a fixed law that other gases unite in definite proportions by volume to form compounds? Do other elements unite in definite proportions by weight? Manifestly the

answer may be obtained by means of some good experiments to illustrate the Law of Constants and the Law of Definite Proportions. We will now consider a few such experiments.

§ 2. Some Experiments to Illustrate the Law of Constants and the Law of Definite Proportions.

(*Note.*—An easy method of filling the eudiometer, to which special attention is directed, is described in Chap. III.)

Ex. 1. Decompose water with an electric current, collecting the gases in separate test-tubes, so as to compare their volumes and to study their properties by igniting. (A good form of apparatus for this purpose is described in Chap. III., § 3.) Collect the gases in one test-tube and ignite. If the student is not satisfied that moisture is formed, it will be necessary to prepare dry hydrogen and burn it in air or oxygen, collecting the product in a cold dry bottle.

Ex. 2. Pass some pure dry hydrogen and oxygen into a eudiometer over mercury. Take care that the gases are at the same temperature. Measure the volume of each gas and explode. Repeat the experiment until the student is convinced that the gases unite in the proportion of 2 to 1, no matter what volume of each gas may be present.

From these two experiments it will be seen (1) that water is constant in composition, (2) that water is a compound, (3) that a definite volume, and hence a definite weight, of hydrogen unites with a definite volume and weight of oxygen to form aqueous vapor.

Let us now consider the question, Do other gases unite in definite proportions by volume? To obtain a satisfactory answer, use dry hydrogen chloride. There are two very important advantages in using this gas to demonstrate these facts. In the first place, only inexpensive apparatus, which is to be found in almost any laboratory, is necessary to per-

form the experiments, and for this reason, the laws may be demonstrated, in this way, by any teacher, while more elaborate and expensive apparatus, such as an induction coil, a battery, and a delicate pair of balances are required for other experiments of this kind. Secondly, the experiments may be used for the purpose of showing that molecules of hydrogen and chlorine each contain two atoms, but at a later stage in the work. The next experiment is taken from Reynolds' "Chemistry."

Ex. 3. (*a*) Open the stopcock (Fig. 1), and pass a current of hydrogen chloride gas through the U tube for some time, then quickly close the stopcock and pour mercury into the U tube to close the bend, and half fill the open arm. Open the stopcock slightly, and allow the gas to escape until the mercury stands nearly the same height in both arms. Mark the height of the mercury in the closed arm. Next drop into the open arm sodium amalgam, and fill to the top with mercury; close the open end with the thumb and pass the gas backward and forward a number of times through the mercury by tilting the tube. Finally hold the tube erect, raise the thumb and allow air to enter the open arm. Pour in or remove mercury until it is the same height in both. The gas in the closed arm should now occupy half the volume that it did at first. Tilt the tube so that the mercury will press on the gas in the closed arm, cautiously open the stopcock and hold the nozzle to the flame. (See also experiment 7, and the chapter on the analysis of gases.)

FIG 1.

(*b*) A modification of the same experiment may be performed as follows: Into a bent tube (Fig. 2), filled with mercury conduct dry hydrochloric acid gas, and then intro-

duce in the bend of the upper part a little piece of dry metallic sodium. On heating the latter with a lamp, the hydrochloric acid is decomposed, the chlorine combines with the sodium to form a sodium chloride while hydrogen is set free. Upon measuring the residual hydrogen, it will be found that its volume is exactly half of the HCl introduced.

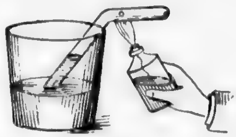


FIG. 2.

In preparing the gases for the next experiment use apparatus described in Chap. III., § 2, Fig. 14, and Chap. III., § 3, Fig. 15.

Ex. 4. Pass equal volumes of pure dry hydrogen gas and chlorine gas into a graduated tube or eudiometer, over mercury, as in Fig. 3 About 6 c.cm. of each will be sufficient. Place the graduated tube in a very dim light while mixing the gases. When the tube is ready, place in the sunlight, or burn magnesium ribbon near it, and chemical union will ensue. If a eudiometer is used, an electric spark from an induction coil may be passed through it. Some water may be passed into the tube by means of a pipette, if considered advisable, when the hydrochloric acid gas will be dissolved.

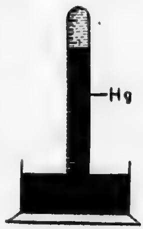


FIG. 3.

An instructor in chemistry may find it an advantage to demonstrate that the laws hold true when solids, or a solid and a gas combine. The three following experiments are recommended, but must not be attempted unless with a delicate balance.

Ex. 5. (*a*) Into a hard glass tube, which has been weighed (Fig. 4), introduce a weighed quantity of copper oxide. About one gram is a convenient amount. Pass dry hydrogen through this tube, and, after all air is expelled, heat the tube

and contained oxide to redness. Weigh the tube and contents, and find the weight of the remaining copper. Calculate the combining weights of oxygen and copper. It is best to have a piece of rubber tubing on the end of the glass tubing, so as to drive off moisture without igniting the surplus gas.

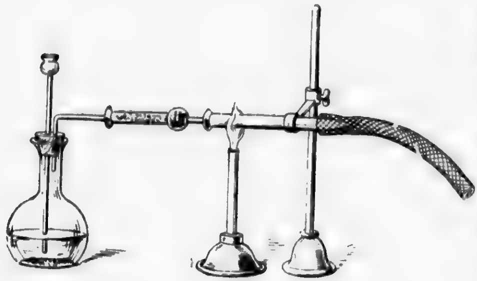


Fig. 4.

(*b*) Heat the copper that is left in the tube in a current of air, and find the weight of CuO that is formed. This may best be done by attaching an aspirator, or a rubber bulb with valve similar to those used in a rubber syringe.

Ex. 6. The following very simple and inexpensive experiment was designed by the writer to illustrate this law, by burning magnesium ribbon (Fig. 5). Take a clear sheet of mica about eight inches long, and four or five inches wide, roll in the form of a cylinder, having the ends overlap about one inch. Firmly fasten the ends together with any good cement. Around the cylinder place a couple of fine rubber bands, to hold it securely. Take two small pieces of mica, to place on top and bottom of the cylinder. These need not be secured.

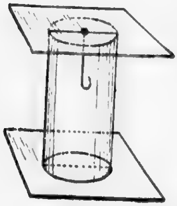


Fig. 5.

Through a small aperture, made with a fine needle in the centre of one, place a piece of platinum wire about one and a half inches long, and fastened at one end to close the

aperture. On the other end of the wire make a small hook. Weigh the apparatus, including the cylinder, two pieces of mica, and platinum wire. Now weigh a piece of magnesium ribbon, about two inches long, hang it very loosely on the hook, and place it through the upright cylinder. Do not let the lower end of the ribbon extend below the lower aperture of the cylinder. Now ignite the magnesium ribbon, and instantly place on the piece of mica. Press on the upper surface of the apparatus, so as not to allow any of the fumes to escape. This is very important. It is best to place the apparatus on a piece of glass or porcelain while burning the magnesium, as the mica becomes quite hot. Weigh the apparatus when cool, and calculate the combining weights of O and Mg. The accuracy of the experiment largely depends upon weighing before and after ignition, at about the same temperature and with the same weight of air present in each case. It may be repeated a number of times without trouble, since it is necessary to shake off only the loose powder before repeating. With a little practice and a delicate balance, this experiment can be quickly and easily done.

Ex. 7. The following experiment is also simple and easily performed. The apparatus is similar to Fig. 1, used in the analysis of hydrochloric acid, and, still more important, may be used in the analysis of gases. The reader's attention is directed to the chapter on this subject.

The piece of apparatus described here is sometimes used as a eudiometer.

Take a U tube similar to Fig. 1, with one arm drawn out to a point, so that a piece of rubber and clamp may be attached, or better, having a stopcock. It is best to have the base of this arm nearly level, as in the diagram, and the base of the second arm rounded. It would also be an advantage to have the arm graduated, but this is not necessary. One

arm of the tube must not hold less than 75 or 80 c.cm. Close the stopcock. Pour in distilled water, and by tilting completely fill the closed arm, and have the water rise a few inches in the open arm. Now carefully weigh out from .150 to .200 gms. of zinc, and drop it into the open arm, and cause it to rest on the level base under the closed arm. A few scraps of platinum might be added. Now pour some strong sulphuric acid into the open arm, and let the gas collect in the closed arm. If the tube is not graduated, place it in a tank of water, and over it a graduate filled with water, and allow the gas to pass into the graduate, so that it can be measured. Bring the water to the same level both inside and outside the graduate. In calculating allow for the tension of the aqueous vapor, the temperature and atmospheric pressure, and determine the weight of H displaced by Zn in H_2SO_4.

Other methods of performing the same experiment will be found in Reynolds' "Chemistry," Chap. X., page 95, Experiment 54; also Remsen's "Chemistry" (Advanced), page 754, which it might be well to consult.

Ex. 8. A method of determining the amount of oxygen in a weighed quantity of potassic chlorate is described in Remsen's "Advanced Chemistry," page 745.

§ 3. How to Represent Molecules and their Reactions upon One Another.

From our experiments we have learned that two or more elements may combine to form a compound. For example, O and H unite to form water, and H and Cl combine to form hydrochloric acid. Now, the smallest particle of any compound or element which can exist by itself, or in a free state, and which still retains the properties of that substance, is called a molecule. Hence it follows that a molecule of water must contain *at least* two parts, or combining units of hydro-

gen, and one part, or combining unit of oxygen; and a molecule of HCl must contain *at least* one part, or combining unit of hydrogen, and one part or combining unit of chlorine. Each particle of hydrogen, oxygen or chlorine which enters into the composition of the molecule, is called an atom. A molecule of water, then, must contain at least two atoms of hydrogen and one atom of oxygen; a molecule of hydrochloric acid must contain at least one atom of hydrogen and one atom of chlorine; and a molecule of cupric oxide must contain at least one atom of copper and one atom of oxygen. Molecules of these compounds are usually written H_2O, HCl, CuO, etc., but it is best also to represent them by diagrams, somewhat as follows:

$$\boxed{H \mid O \mid H}, \quad \boxed{H \mid Cl}, \quad \boxed{Cu \mid O}, \quad \boxed{Mg \mid O}.$$

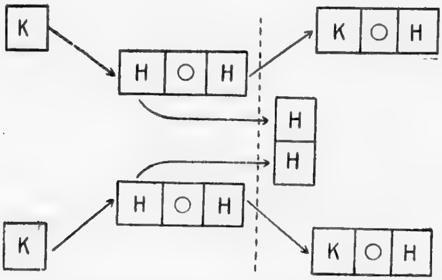
By means of these the beginner may form a mental picture of how the atoms are held together in the molecules.

Just at this stage in the work the student should learn what the symbols of chemical notation, such as Cl, H, O, etc., denote; what is indicated by the formula of a compound, as, H_2O, CuO, MgO, etc.; and further, that the electro-positive element stands first in the formula. This should be followed by the preparation of hydrogen gas from the acids and such metals as zinc, magnesium, etc.; also from water by using potassium and sodium, as these experiments will best serve the purpose we have in view.

Having performed these experiments, it will be an advantage to make diagrammatic representations of the molecules of substances used and formed, when these chemical changes took place. For example, potassium hydrate, $\boxed{K \mid O \mid H}$, sodium hydrate, $\boxed{Na \mid O \mid H}$, and other formulæ not in the

previous paragraph, might be written out. The transmutations in these experiments might now be represented somewhat in this way:

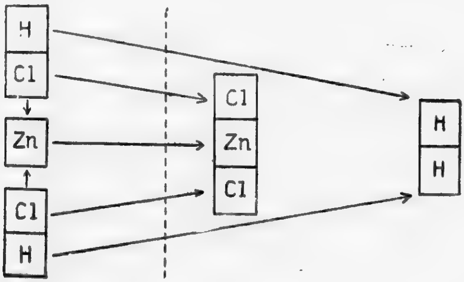
(1) When potassium is thrown on water, hydrogen and potassium hydrate are formed.



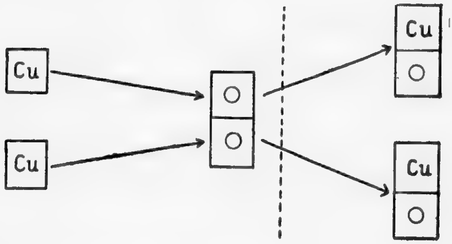
(2) When sodium is thrown on water, hydrogen and sodium hydrate are formed.

This may be represented by a diagram similar to the action of potassium on water (1). For a representation of this see § 10 of this chapter, page 37.

(3) When hydrochloric acid is poured on zinc, hydrogen and zinc chloride are formed.



(4) When copper is heated in a current of air, oxide of copper is formed.



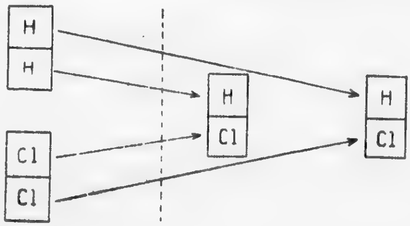
(5) When hydrogen is passed over CuO, water and copper are produced.

For a diagram of this reaction see § 10 of this chapter, page 38.

(6) When magnesium is heated in air, oxide of magnesium is formed.

This may be represented by a diagram similar to the action of oxygen on copper (4).

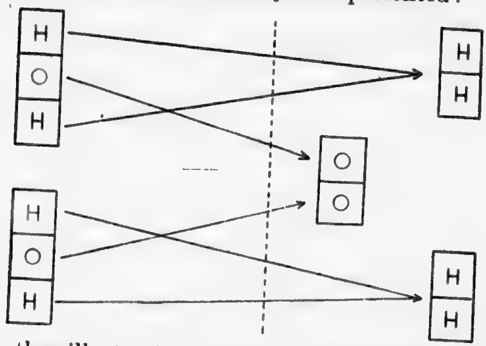
(7) The synthesis of hydrochloric acid may be represented :



(8) The analysis of hydrochloric acid may be demonstrated as in diagram, § 10 of this chapter, page 36.

(9) The synthesis of water may be represented as in diagram, § 10 of this chapter, page 37.

(10) The analysis of water may be represented:



Many other illustrations might be added, such as the action of sulphuric acid on zinc, and on magnesium; the heating of potassic chlorate, mercuric oxide, etc., but enough have been used to indicate the method.

In the preparation of hydrogen, and in many other introductory experiments, the more important acids have been used, and the beginner will be familiar with their common names. These may be used to good advantage to introduce the formulæ of compounds.

§ 4. The Formulæ of Compounds.

Like water, the acids are compounds of hydrogen, or contain displaceable hydrogen, as shown in the preparation of hydrogen gas; and such compounds of hydrogen may be written somewhat as follows:

H_2O, HOH, HCl, HI, HBr, HNO_3, H_2S, H_2SO_4, H_2CO_3, H_3PO_4, etc.

Besides the common names, water, hydrochloric acid, nitric acid, etc., these compounds are called hydrogen oxide, hydrogen chloride, etc.

When potassium was thrown on water, an atom of K took the place of one atom of H, and formed KOH. If another atom of K were to take the place of the atom of hydrogen,

we would have K_2O, the oxide of potassium. Other compounds of potassium may be formed by displacing the hydrogen of the acids with K, one atom of K taking the place of one atom of hydrogen. In this way we may write down the compounds of potassium corresponding to those of hydrogen: KCl, KI, KNO_3, KBr, K_2S, K_2SO_4, K_2CO_3, K_3PO_4, etc. In the same way the compounds of sodium may be written out.

Now let us look at magnesium. The oxide is written MgO. Then an atom of Mg just takes the place of two atoms of hydrogen, as the oxide of hydrogen is written H_2O. Hence the sulphate of magnesium will be $MgSO_4$, its sulphide MgS, and its carbonate $MgCO_3$. Since one atom of hydrogen combines with one atom of chlorine to form HCl, an atom of magnesium will combine with two atoms of chlorine to form magnesium chloride, $MgCl_2$. Then its other compounds will be written $Mg(OH)_2$, MgI_2, $MgBr_2$, $MgNO_3$, etc.

The table, as it appears on the blackboard, will be:

Oxides.	Hydrates.	Chlorides.	Bromides.
H_2O	HOH	HCl	HBr
K_2O	KOH	KCl	KBr
Na_2O	$NaOH$	$NaCl$	$NaBr$
MgO	$Mg(OH)_2$	$Mg(Cl)_2$	$Mg(Br)_2$
Iodides.	**Nitrates.**	**Sulphides.**	**Sulphates.**
HI	HNO_3	H_2S	H_2SO_4
KI	KNO_3	K_2S	K_2SO_4
NaI	$NaNO_3$	Na_2S	Na_2SO_4
$Mg(I)_2$	$Mg(NO_3)_2$	MgS	$MgSO_4$

Zinc and copper might be added to this list as practice for the student, but before writing out any more compounds it will be necessary to get a clear idea of how the elements combine with one another, and this can be done by a study of Mendelejeff's classification.

§ 5. MENDELEJEFF'S TABLE.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
R_2O	RO	R_2O_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
H 1.							
Li 7.0	Be 9.0	B 10.8	C 11.91	N 13.95	O 15.88	F 18.9	
Na 22.87	Mg 23.8	Al 26.9	Si 28.2	P 30.8	S 31.82	Cl 35.19	
K 38.84	Ca 39.7	Sc 43.8	Ti 47.8	V 50.8	Cr 51.8	Mn 54.5	Fe 55.6 Co 58.4 Ni 58.3 Cu 63.1
Cu 63.	Zn 64.8	Ga 69.6	Ge 71.9	As 74.5	Se 78.5	Br 79.36	
Rb 84.8	Sr 87.0	Y 88.5	Zr 90.0	Nb 93.2	Mo 95.3		Ru 100.9 Rh 102.2 Pd 105.8 Ag 107.12
Ag 108.	Cd 111.2	In 113.0	Sn 117.2	Sb 119.0	Te 124.4	I 125.90	
Cs 132.0	Ba 136.4	La 137.5					
		Er 165.0					
				Ta 181.1	W 183.0		Os 189.3 Ir 191.5 Pt 193.33 Au 195.7
	Hg 198.8	Tl 202.7	Pb 205.4	Bi 207.3			
			Th 230.7		U 237.6		

In studying this table with the class it is best to have a large chart made, showing the elements with their atomic weights, and have it hung in a conspicuous place. The elements are arranged, in the classification here presented, in eight vertical columns, representing eight groups; while successive series are presented in horizontal lines. (These may be made to incline slightly, so that on rolling the table Na will immediately succeed F, K will succeed Cl, and so on, in a spiral line. See Shepherd's "Chemistry," page 221.) The first eight present very marked individual characteristics. The teacher should not draw attention to too many facts at first, but only give such information as will be useful in illustrating the way in which elements unite to form compounds. If too much is attempted it may lead to confusion, and the teacher must use his own judgment as to what is necessary. The following might be made clear:

1. The elements are in the order of their atomic weights.

2. The meaning of RO, R_2O, R_2O_3, etc., RH_4, RH_3, RH_2, RH, etc.

3. The elements of each group have a series of compounds corresponding to the oxides.

4. One atom of Cl, Br, etc., unites with one atom of H, and hence with one atom of each element in Group I. The other groups form similar compounds.

5. The position of the metallic and non-metallic elements in the table.

The next step in the work is quite plain. The student should write out a series of compounds, or at least one element in each group, similar to those of H, Na, etc., already given, but it should be made plain that many of these have compounds corresponding to the elements in other groups, and that the elements of each group should be memorized. In connection with this study the subject of valence, and the

meaning of univalent, bivalent, trivalent elements, etc. should be considered. This introduces chemical nomenclature and the principles upon which the names of compounds in inorganic chemistry are based.

The following explanation of valency, which is condensed from two or three different text-books of chemistry, indicates a line which may be followed in considering the subject. All quotations are marked.

§ 6. Valence.

Our study of Mendelejeff's table has demonstrated clearly that "elements or radicals have the property of combining with or replacing other elements or radicals in definite and constant proportion. The degree of this property is commonly indicated by the number of atoms of hydrogen with which the atom or radical can combine or which it can replace. The combining capacity of hydrogen is taken as the unit, hence hydrogen is said to have a valence of one." Thus it will be seen that the valency may be ascertained from the composition of the hydride; where no such compound exists then the most stable oxide or chloride may be used. The hydrides in Mendelejeff's table are represented:

$$RH_4, \quad RH_3, \quad RH_2, \quad RH.$$

By writing down the hydrides of the different elements and their atomic weights we learn that, "in each group the affinity of the elements for hydrogen diminishes step by step with the increasing atomic weight; nevertheless, the number of hydrogen atoms which combine with one atom of each of the other elements is constant for each group." This is what is called valence or atomicity, and may be defined as "the function of affinity of an element in its relation to hydrogen," or referred to the combining power of hydrogen as a unit. To determine, then, the valency of the more important elements, let

us examine their hydrides or chlorides. One atom of hydrogen unites with one atom of each element of the chlorine group. Hence the halogens possess one affinity unit and are monovalent. Sulphur and oxygen each unite with two atoms of hydrogen or chlorine, and since they possess two affinity units they are divalent, *i.e.*, an element which will not combine with more than two atoms of hydrogen or chlorine, or will not displace more than two atoms of hydrogen is divalent. For similar reasons nitrogen and arsenic are trivalent, and carbon and silicon tetravalent. "Nor can one atom of chlorine, sulphur, nitrogen or carbon be made to combine with more than one, two, three and four atoms of hydrogen respectively, to form stable and definite compounds. They are satisfied, or saturated, and these compounds are termed saturated compounds."

"Chemical affinity, however, must not be confused with valency. Valency is quite independent of affinity, and peculiar to individual elements." Carbon combines with four atoms of chlorine, sulphur with two, and hydrogen with one atom to form saturated compounds, but this does not indicate that carbon has a greater affinity for chlorine than sulphur or hydrogen. Very often the opposite is the case. "Those elements which have the greatest chemical affinity have often the lowest valency, and inert bodies, such as those of Group IV. and Group VIII., have often the highest valency."

A study of the equivalent weights of the elements will also aid in determining their atomicity. It has been found by actual experiment that 23 grams of sodium liberate from water 1 gram of hydrogen; 24 grams of magnesium or 65 grams of zinc displace 2 grams of hydrogen from the hydrogen compounds, and 27 grams of aluminium liberate 3 grams of hydrogen; also 12 grams of magnesium displace 108 grams of silver from silver nitrate. The weight obtained in each case is

known as the equivalent weight when referred to hydrog as unity. In the case of sodium and the other elements Group I., the equivalent weights are identical with the atom weights. The equivalent weights of magnesium and the othe elements of Group II. are proportional to half the atomi weights; and those of aluminium and Group III. to one-thir the atomic weights. Since the equivalent weights of sodium and the other elements of Group I. are identical with the atomic weights, they are monovalent. The equivalent weights of magnesium and zinc are respectively 12 and 32.5, and the atomic weight is in each case double the equivalent weight; hence these and other elements of Group II. are divalent. In the case of aluminium, the atomic weight is three times the equivalent weight; therefore aluminium and the other elements of Group III. are trivalent.

From what has been pointed out it will be seen that there is a "periodic relation between valency and atomic weights." In general the members of Group I. are monovalent, Group II. are divalent, Group III. are trivalent, Group IV. are tetravalent, Group V. are pentavalent or trivalent, Group VI. are hexavalent or divalent, Group VII. are heptavalent or monovalent, Group VIII. are octovalent or divalent. It must be remembered, however, that there are compounds which prove exceptions to this general statement, and to obtain a full appreciation of the subject we must study the "constitution of the chemical compounds." In order to do this chemists have adopted a symbolic method of representing the formulæ, "which serves to give expression not only to the proportion in which the elements combine, but also to the distribution of the atoms within the molecule, and their mode of attachment to one another." It is the opinion of the writer that it is not best to introduce graphic formulæ until the students have learned to write a chemical equation.

§ 7. An Explanation of the Law of Multiple Proportions, the Law of Definite Proportions, and Avogadro's Law.

We are now in a position to consider the Law of Multiple Proportions, which forms an essential amplification of the Law of Definite Proportions; and perhaps the Law of Multiple Proportions can best be explained by calling attention to the oxides of nitrogen.

A study of this law leads us to a consideration of the most important principles of chemistry. Dalton made the great discovery that "elements unite in definite proportions by weight," and applied to his discovery the atomic theory. This grew out of a crude analysis of matter, which proved to his mind, at least, that the same substance always had precisely the same composition, as Proust and other investigators had already written on the "constancy of the relations by weight of the component parts of bodies." We now know this fact as the Law of Constants, namely, that "matter is constant in composition," or in other words, that "all compounds are definite, and contain only certain determinate proportions of their constituents." Gay Lussac then discovered that gases unite in definite proportions by volume; and finally Avogrado made a distinction between atoms and molecules, and from these facts built his great hypothesis. This made a revolution in chemical science, and nothing is clearer than that the student should think out for himself the reasons which led to such conclusions. No other statement or apology is necessary why an epitome of these facts, which are fully explained in Richter's and other text-books, with some of the writer's own observations, should be given in the next few paragraphs. The question now assumes the form, What is the best explanation of these great principles?

"The Law of Constant or Definite Proportions finds its

best explanation in the hypothesis of the existence of aton which Dalton first applied to explain this law. It was duri his investigations on marsh gas and olefiant gas that t atomic theory first suggested itself to Dalton. He calculate that if the weight of carbon in each of these compounds we reckoned to be the same, then marsh gas contained twic the weight of hydrogen present in olefiant gas. He furthe observed that the quantity of oxygen in carbonic acid ga (CO_2) was twice as much as carbonic oxide gas (CO). These and similar facts he conceived, might be explained by assuming that matter consists of extremely small particles which cannot be further divided, either chemically or mechanically; or, in other words, that matter consists of atoms possessing definite weights, the ratios of which could be denoted by numbers, the weight of an atom of hydrogen being taken as unity. Further, he conceived that the atoms of different elements possess different weights, and all atoms of one element have the same absolute weight and are like each other. The combination of these atoms with one another would account, then, for the definite proportion in which the elements united, and the weight of the smallest particle or molecule of a compound might therefore be obtained by adding together the weights of its constituent atoms. On such a basis we see that the constituents of compounds should be constant."

"The consideration of the Law of Multiple Proportions brings out the fact that the halogens unite with hydrogen in only one proportion, and when we compare the proportions in which these elements combine, with their densities, we are forced to the conclusion that in equal volumes of these elementary gases there is contained an equal number of atoms, or combining units. If in one volume of hydrogen, for example, there are 1000 atoms, which equal 1000 weight units,

and in a like volume of chlorine there are 1000 atoms of chlorine, which $= 1000 \times 35.45$ weight units, then it is evident that the relation between the atomic weights and that between the densities must be the same, or one volume of hydrogen $= 1000 \times 1$, and one volume of chlorine $= 1000 \times 35.45$. Hence the atomic weights of the halogen elements are proportional, or equal to their densities if referred to the same unit.

We arrive at a perfectly similar, but much more general, conclusion, by the consideration of the physical properties of gases or vapors. According to the law of Mariotte and Boyle, "the volume of a gas at constant temperature varies inversely as the pressure," and from the law of Charles and Gay Lussac we learn that, "the volume of a given gas at a constant pressure varies directly as the absolute temperature," etc. From this we infer that when we have the smallest particles which can exist in a free state, and the gas expands from an increase of temperature, the particles do not increase in number, nor do they increase in size, but the spaces between the particles must become larger. In other words, when heat or energy is transferred to a volume of gas, the temperature increases, and each particle receives the same amount of energy. Hence, according to the kinetic theory of gases, they are driven apart, or affected, to the same extent, so that the spaces between the particles must increase to the same extent. Now, it necessarily follows that if equal volumes of different gases change to the same extent when subjected to equal alterations in temperature and pressure, "there must be an equal number of particles contained in equal volumes." From this it is inferred that their relative weights are proportional to their volume weights, or gas densities.

Now we can appreciate the historical order of these dis-

coveries, and the important question again arises, How gases combine by volume? The analysis and synthesis hydrochloric acid and water make this point plain.

From these experiments we learn the following:

1 volume of H + 1 volume of Cl = 2 volumes of HCl;

also, 2 volumes of H + 1 volume of O = 2 volumes of H_2O.

As a confirmation of our experiments, we are aware tha Gay Lussac discovered (1) that gases unite according to sin ple volume ratios, and (2) that the volume of the resultin body bears a simple ratio to the volumes of the constituents Dalton discovered that the quantities by weight of the com bining elements also bear a simple ratio to one another. I we grant the atomic or molecular constitution of matter Avogadro's hypothesis follows, namely, "that equal volumes of gases under the same conditions of temperature and pres-sure contain the same number of particles or molecules."

Having proved the truth of these laws we may infer con-cerning hydrochloric acid, that since, according to Avogadro's law, "equal volumes of gases under the same conditions of tem-perature and pressure contain the same number of molecules,"

Then 1 molecule of hydrogen + 1 molecule of chlorine = 2 molecules of HCl;

Hence $\frac{1}{2}$ a molecule of H + $\frac{1}{2}$ a molecule of Cl = 1 molecule of HCl;

Therefore a molecule of Cl and a molecule of H each con-tain at least two atoms.

A similar inference may be drawn from the analysis and synthesis of water.

2 molecules of hydrogen + 1 molecule of oxygen = 2 mole-cules of water vapor;

Therefore 1 molecule of hydrogen + $\frac{1}{2}$ a molecule of oxygen = 1 molecule of water vapor;

Hence we infer that a molecule of oxygen is divided into 2 parts, or contains *at least* 2 atoms.

§ 8. Molecular Volume and Atomic Weight.

We have already pointed out that the relative weights of gases are proportionate to their densities, and in determining their densities that hydrogen is taken as a unit. In other words, to obtain the density of any gas, we divide the weight of a certain volume by the weight of an equal volume of hydrogen at the same temperature and pressure. It will be manifest, therefore, from Avogadro's hypothesis, that if we divide the weight of a certain number of molecules by the weight of an equal number of molecules of hydrogen, we also get the density; and, further, we arrive at the same result by dividing the weight of one molecule of the gas by the weight of a molecule of hydrogen. It is quite apparent, then, that we may obtain the weight of a molecule of any gas by multiplying the density of the gas by the weight of a molecule of hydrogen. The reverse of this is also true; we may obtain the density from the molecular weight, which is very important to the beginner in studying the properties of gases.

To determine the weight of a molecule, however, we must know the number of atoms in a molecule and the weight of an atom. It is certain, then, that the student will need to have a clear conception of "molecular volume" and "atomic weight," and it must be made plain that the molecule exists only in theory, but that the assumption of its existence serves, at present, as the best means of explaining chemical phenomena. We are ignorant of both the form and character of the molecule, and any measurements which have been made of its volume are approximations. To say that a molecule is invisible to the highest powers of the microscope does not by any means give an idea of its volume. Sir W. Thompson estimated the diameter to be about one ten-millionth of a millimeter; but it would take a considerable stretch of the imagination to even conceive of a particle of such

minute dimensions. Such measurements are interesting, h ever, as they tend to support the view that ultimate parti of matter, though extremely small, have a definite size. will be quite apparent, then, that the weight of an a cannot be actually determined, but the weight of an aton hydrogen has been adopted as unity, and all measureme have been made relatively to its weight. Since, then molecule of hydrogen contains two atoms, and an atom hydrogen weighs one, its molecular weight is two, and molecular weight of any gas is equal to the density of the in its relation to hydrogen multiplied by two. Then, too must be apparent that if we take a volume of hydrog which weighs two (its molecular weight), an equal volume any other gas at the same temperature and pressure m weigh its molecular weight. Therefore, if a volume of hyd gen weighs two pounds, grams or ounces, an equal volume any gas at the same temperature and pressure will weigh number of pounds, grams or ounces corresponding to molecular weight.

We might very properly at this point discuss the metho of determining the atomic weight of an element, but it w be sufficient for our purpose to state that in determining t atomic weight of any element we must (1) find the molecul weight of all compounds containing the element by the metho already indicated, and then (2) from an analysis of its com pounds calculate the smallest amount of the element in th molecular weight of each of its compounds. This will giv the atomic weight, which may be defined as "the smalle weight of that element which enters into a molecule of i compounds."

Now we are in a position to appreciate a simple method determining the molecular weight of any gas. 22.4 litres hydrogen at 0° C. and 760^{mm} barometric pressure weigh 2 gram

But 2 is the molecular weight of hydrogen, and since by Avogadro's law, "equal volumes of gases under the same conditions of temperature contain the same number of molecules," it follows that 22.4 litres of any gas at 0° C. and 760^{mm} barometric pressure must weigh its molecular weight in grams. 22.4 litres of chlorine at 0° C. and 760^{mm} weigh 71 grams, therefore 71 is its molecular weight; 22.4 litres of ammonia at the same temperature and pressure weigh 17 grams, and 17 is the molecular weight of ammonia. On the other hand, if we know the number of atoms in a molecule, and the weight of each atom, we can calculate the weight of 22.4 litres of the gas at standard temperature and pressure. In ammonia, for example, there are three atoms of hydrogen and one atom of nitrogen; an atom of hydrogen weighs 1 and an atom of nitrogen weighs 14, therefore the molecular weight is $3 + 14 = 17$. Hence it follows, from what has been said, that 22.4 litres of ammonia gas at standard temperature (0° C.) and pressure (760^{mm} B. P.) weigh 17 grams. For the same reason 22.4 litres of marsh gas (CH_4) at standard temperature and pressure weigh $12 + 4 = 16$ grams.

For the above reasons, it will be important to know the number of atoms in a molecule of the different elements. There are two atoms in a molecule of each of the more common gases, such as H, Cl, O, etc. Potassium, sodium, zinc and mercury have one atom in a molecule, and recent investigations on the new gases, argon and helium, indicate that there is but one atom in a molecule of each of these elements. It is interesting here to note that recent investigations indicate that arsenic is not an element, but a compound of phosphorus.

The following table is interesting, and should be stu
by the class.

	Vapor Density (H = 1).	Atomic Weight.	Number of Atoms in a Molecule.	Molecular Weight.	Molecular
Hydrogen	1.0	1	2	2	H_2
Nitrogen	14	14	2	28	N_2
Oxygen	16	16	2	32	O_2
Chlorine	35.4	35.4	2	70.8	Cl_2
Sodium	11.5	23	1	23	Na
Potassium	19.5	39	1	39	K
Zinc	32.5	65	1	65	Zn
Cadmium	55.8	111.7	1	111.7	Cd
Mercury	100	200	1	200	Hg
Iodine at 450° C.	126.5	126.5	2	253.0	I_2
Iodine at 1500° C.	63.3	126.5	1	126.5	I
Sulphur at 500° C.	96	32	6	192	S_6
Sulphur at 1000° C.	32	32	2	64	S_2
Ozone	24	16	3	48	O_3
Phosphorus	62.0	31.0	4	124	P_4
Arsenic	159.8	74.9	4	299.6	As_4

§ 9. What is an Element?

During all this time the student has been studying elemen
and compounds, but it is certain he will not be able to te
why hydrogen, iron or calcium, for example, are classified a
elements. This is something which should be settled at onc

What reasons, then, have we for believing that hydroge
is an element? The following are some reasons, but any o
of them must not be regarded as a reason in itself.

resting, and should be studi

Atomic Weight.	Number of Atoms in a Molecule.	Molecular Weight.	Molecular Formula.
1	2	2	H_2
14	2	28	N_2
16	2	32	O_2
35.4	2	70.8	Cl_2
23	1	23	Na
39	1	39	K
65	1	65	Zn
1.7	1	111.7	Cd
0	1	200	Hg
6.5	2	253.0	I_2
6.5	1	126.5	I
2	6	192	S_6
2	2	64	S_2
3	3	48	O_3
.0	4	124	P_4
.9	4	299.6	As_4

Element ?

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reason in itself.

1. Hydrogen has a characteristic spectrum, as in the case of other elements.

2. Its atomic weight has been determined by a number of different methods, and has been found to be constant.

3. Chemists have never been able to obtain anything from it but hydrogen. It has never been decomposed.

4. All its compounds are constant in composition; it unites in definite proportions by weight with other elements, and it follows the Law of Multiple Proportions in forming its compounds, as for example, H_2O and H_2O_2.

5. Hydrogen occupies a definite position in Mendelejeff's classification, and its atomic weight is such as to lead us to believe that it is an element, from its relation to other atomic weights in that classification.

6. It forms a series of compounds similar to those of Group I of Mendelejeff's classification, and it may be displaced in those compounds by many other substances which we believe to be elements; and both hydrogen and its compounds have properties similar to those we would expect an element and its compounds to have which would occupy the position it occupies in the table.

For similar reasons other substances are classified as elements.

While studying the relation of hydrogen to other elements, one other point should be made clear. Is hydrogen a metal or a non-metal? The answer we get will aid very materially in understanding its compounds, and their relation to the compounds of other elements. For the following and other reasons, it is believed to be a gaseous metal at ordinary temperatures.

1. Hydrogen is absorbed by the metal palladium, and the compound conducts itself like an alloy of two metals, being

metallic in appearance, and having the power of conducti heat and electricity.

2. When water is decomposed hydrogen appears at t electro-negative pole, as other metals when their salts a decomposed.

3. It possesses the power (in marked degree for a gas) conducting heat and electricity.

4. Hydrogen is absorbed by the metals potassium an sodium, forming alloys, in which the density of H is .62.

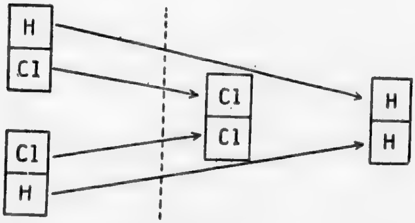
5. Liquid hydrogen is said to have a metallic appear ance, etc.

6. The element displays the character of a metal in it chemical deportment.

§ 10. THE CHEMICAL EQUATION.

We are now in a position to write and understand what denoted by a chemical equation. Let us begin by writin out what took place in the analysis and synthesis of hydr chloric acid, as we had evidence in those experiments that molecule of H and a molecule of Cl each contained two atom (At this point the signs should be fully explained.)

(1) When hydrochloric acid is decomposed, hydrogen an chlorine are formed.



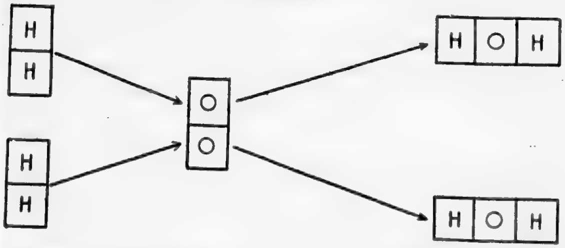
This may be expressed: $2HCl = Cl_2 + H_2$.

(2) When hydrogen and chlorine combine, hydrochloric acid is formed

For a diagram of this reaction see § 3 of this chapter, p. 19.

This may be written: $H_2 + Cl_2 = 2HCl$.

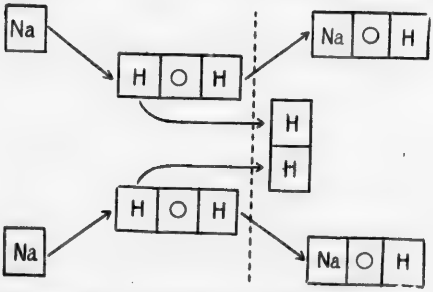
(3) Now represent what takes place with water. When O and H combine H_2O is formed.



This may be represented: $2H_2 + O_2 = 2H_2O$.

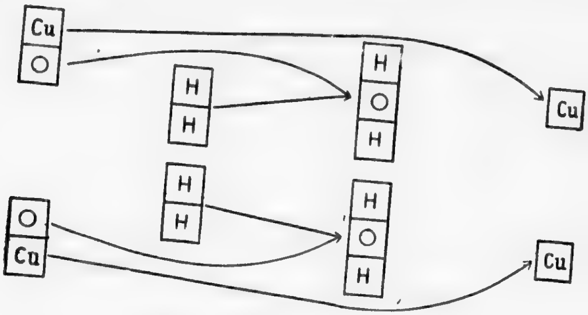
The student writes out the molecular equation, and does not need to write the equation in the atomic form, to which so many chemists seriously object. Further, he is able to understand everything that is denoted by the equation, and it should be fully explained that what is represented by the equation is true both by weight and by volume.

(4) When sodium is thrown on water, hydrogen is formed.



This is expressed: $2Na + 2H_2O = H_2 + 2NaOH$.

(5) When hydrogen is passed over copper oxide it ma
represented :



$$2CuO + 2H_2 = 2H_2O + 2Cu.$$

All the student will need now is some practice in writi out a few simple equations in this way. Then he will need little practice in balancing an equation, after he has writt down the formulæ of substances used and produced. It w be surprising how quickly he gets over the difficulty. Tl plan has never been found to fail.

This section would be incomplete without answering th question, What chemical information does a typical equatio convey ?

It will be observed, by way of introduction, that the sub stances which react upon one another to produce a chemica change, are always placed at the left-hand side of the equa tion, and the compounds produced are placed to the right The sign + indicates that the substances are brought togethe under such conditions that they react upon one another, an the sign = means that they "give" or "produce" the sub stances on the right-hand side of the equation. The number placed to the left of each molecular formula denotes the num ber of molecules, and the numbers placed at the base of eac

symbol denote the number of atoms of that particular element in a molecule; thus, $2H_2O$ denotes that there are two molecules of water, and each molecule contains two atoms of hydrogen and one atom of oxygen; $KClO_3$ indicates that there is one molecule of potassic chlorate, which contains one atom of potassium, one atom of chlorine, and three atoms of oxygen. Further, $KClO_3$ indicates that a molecule of potassic chlorate weighs $(39 + 35.4 + 3 \times 15.96)$ or 122.28, which is the sum of the weights of the atoms; $2KClO_3$ would be twice this amount.

Let it not be forgotten that an equation is based on the indestructibility of matter; in other words, matter may be transformed, but cannot be destroyed. The total weight of the substances reacting on one another must be equal to the sum of the weights of the substances produced, and to obtain such a result the number of atoms on one side of the equation must be equal to the atoms on the other. Further, when the elements and compounds used and produced are in the gaseous state, the numbers indicating the molecules used will indicate the proportions by volume in which the gases combine, and the numbers denoting the molecules produced will indicate the volumes produced when in the gaseous state. For example,

$$2H_2 + O_2 = 2H_2O.$$

This expresses what we learned by experiment:

1. That 2 volumes of hydrogen + 1 volume of oxygen produces 2 volumes of water vapor, calculated at the same temperature and pressure. The water must be in the gaseous state.

2. Hence, from Avogadro's law 2 molecules of hydrogen + 1 molecule of oxygen produces 2 molecules of water vapor at the same temperature and pressure.

3. 4 by weight of hydrogen $(2 \times 2) + 31.92$ (2×15.96) by weight of oxygen produces 35.92 by weight of water vapor.

This proportion holds, no matter in what denomination weights are expressed—pounds, ounces, or grams.

The proportions by volume do not hold true unless substances are in the gaseous state.

This should be followed by the consideration of a problems in chemical arithmetic.

§ 11. Graphic Formulæ of Volatile Compounds.*

It will now be in order to study the graphic formulæ compounds. The valency is indicated by means of lines proximity to the symbol, and may be drawn in any convenie position.

The molecule of hydrogen is H—H, the atom H—

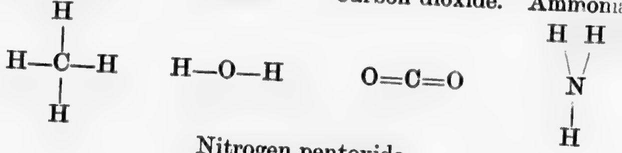
" " oxygen is O=O, " O= or —O

" " nitrogen is N≡N, " N≡ or $\diagdown\diagup$ N |

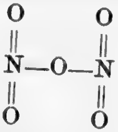
or N≣N, the atom =N≡ or —N— (with \ / above and | below)

Compounds may be represented:

Marsh Gas. Water. Carbon dioxide. Ammonia



Nitrogen pentoxide.



Unsaturated Compounds.—We have already considered saturated compounds. There are certain compounds, how

* From Bailey's "Tutorial Chemistry."

ever, in which valency is not exercised to the full extent; these are termed unsaturated compounds. For example, in marsh gas carbon is associated with four atoms of hydrogen, while in ethylene each atom of carbon is associated with two atoms of hydrogen, and in acetylene with one. Thus:

$$\begin{array}{ccc} \mathrm{H—C—H} & \qquad & \mathrm{C—H} \\ \| & & ||| \\ \mathrm{H—C—H} & & \mathrm{C—H} \\ \text{Ethylene.} & & \text{Acetylene.} \end{array}$$

It is assumed in such cases that certain valencies are suppressed or latent. Carbon monoxide and nitric oxide are also examples of latent valency.

$$\begin{array}{ccc} \mathrm{=C=O} & \qquad & \mathrm{—N=O} \\ \text{Carbon monoxide.} & & \text{Nitric oxide.} \end{array}$$

Such bodies are usually characterized by the ease with which they enter into further combination with elements or groups of elements to form saturated compounds. Ethylene in the presence of chlorine gas forms ethylene dichloride, $C_2H_4Cl_2$, commonly known as "Dutch liquid," and chlorine unites directly with carbon monoxide to form ($COCl_2$) phosgene gas; nitric oxide unites readily with ferrous salts, and with chlorine; in the former case it is used as a test for nitric oxide, and in the latter it forms nitrosyl chloride (NOCl).

There is another problem which every teacher must have met. Why, for example, does the body A react upon the body B, and produce the bodies C and D? Few students have not asked the questions, How can I predict when A will react upon B? and, If the bodies A and B react upon one another, what substances will be produced? The answer lies at the very foundation of analytical chemistry, and it may be a long time before we can say to the beginner, "This reaction will take place, because," etc. Nevertheless, every teacher should become familiar with the developments in physical chemistry throwing light upon this interesting question.

CHAPTER II.

HOW TO HANDLE NOXIOUS GASES IN THE OPEN LABORATORY.

THIS is a very important question, as the health of
experimenter often depends upon the judicious handling
noxious gases produced in his work. No student or teac
can retain his health in an atmosphere which is vitiated w
sulphuretted hydrogen, chlorine, nitric oxide, or with
fumes of strong acids which are constantly used in the labo
tory. When the general health of a class in practical che
istry is imperilled, it becomes a very serious question. So
instructors may not be willing to admit it, but it is, nev
theless, a fact, that any teacher who attempts to handle,
permits his pupils to study, noxious gases by following t
methods described in our ordinary text-books, takes a su
course of destroying his own health and that of the studen
he has under his charge. Since this is the case, it is n
surprising to find that many contend that practical wo
should not be attempted in a laboratory which is not su
plied with suitable draught cupboards; and I am inclined
think that is the proper position to take, if other means ca
not be found to overcome the difficulty. Having had son
experience in such a laboratory, I set about to devise a simp
method of overcoming the difficulty, and happily succeede
so far as it is possible to succeed without incurring very grea
expense, as the following plan will show.

ER II.

XIOUS GASES IN THE
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§ 1. Sulphuretted Hydrogen in Qualitative Analysis.

Sulphuretted hydrogen, for example, is used so extensively in analytical work, that it becomes absolutely necessary to have a convenient method of disposing of the surplus gas. This is the end I have had in view in all experiments described in this chapter. To overcome the difficulty, I have found it absolutely necessary to use rubber tubing and rubber stoppers. It may not always be easy to make the tubing and corks to fit; but some hints are given at the end of the book which will aid in this respect.

Take a large glass jar, and fit it with a double perforated rubber stopper, or what is better, use a Wolff bottle, with two necks, which will hold one or two quarts. Place in the necks of the bottle (Fig. 6, *a*), perforated rubber stoppers (*b*) and (*c*). Through one (*b*) pass a glass tube (*d*), which fits tightly in the stopper, and which passes to the bottom of the

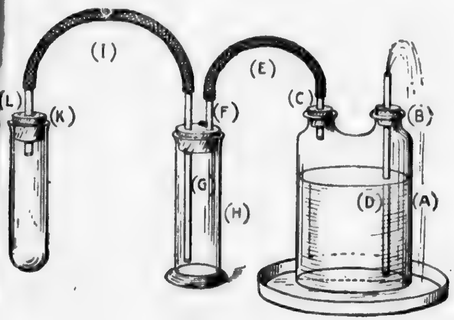

Fig. 6.

jar (*a*). Through the other stopper pass a short glass rod, and connect this rod by a rubber tube (*e*) about twelve inches long to a test-tube or bottle (*h*), in which the solution to be precipitated is placed. In the mouth of this test-tube or bottle place a double perforated stopper. Through one perforation pass a long glass tube (*g*), which reaches nearly to the bottom of the test-tube, and through the other perfora-

tion a piece of tubing (f), long enough to connect with tubing (e) of the Wolff bottle. Connect the longer glass t (g) with the flask or test-tube (k, fitted with a perfor rubber stopper (l) and glass tube), in which the gas is ma factured. See that all stoppers are air-tight.

Now fill the jar (a) with water, and place in a tank deep plate, to gather water which flows from the tube Place the solution to be tested in the test-tube (h), and ge rate the gas in the test-tube or Florence flask (k). The passes through the solution in (h), and the surplus gas pa into the jar (a), forcing the water up through (d). It is b to have the tube (g) so that it can be pulled up and do easily through the stopper. When the solution has b tested remove the test-tube (h), and put an empty test-tu or one containing a little water, in its place, so as to wash any solid formed on the glass rod.

For a test-tube rack, a couple of quinine bottles, or tin ca about six inches deep, with cotton batting in the bottom, very convenient to keep the test-tubes in place.

Sulphuretted Hydrogen Water.—To manufacture hydrog sulphide water, place a quinine bottle fitted with a dou perforated rubber stopper in place of the tube (h). Fill with water, and let the gas bubble up through it as long desired.

Chlorine water, ammonium sulphide and hydrogen iodi may be manufactured in the same way.

If the stoppers fit tightly it is possible to handle any g without allowing it to escape into the room.

From what has been stated, it will be observed that st dents may study many gases with a modified form of th apparatus, as shown in Fig. 7. This is the case with hydr gen, oxygen, nitrogen, monoxide, etc.; but to make a succe of chlorine, hydrogen sulphide and sulphur dioxide, apparatu similar to that described in Fig. 6 must be used. Each pai

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Connect the longer glass tub
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water, and place in a tank o
hich flows from the tube (*d*
in the test-tube (*h*), and gen
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etc.; but to make a succe
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students should have test-tubes, quinine bottles and a large glass jar, fitted as in Fig. 6; also an extra stopper, to attach to surplus jar, as in Fig. 9, and test-tubes fitted, as in Fig. 8. Experience has shown that it is best to use quinine bottles in place of (*h*) Fig. 6, when studying the properties of chlorine, sulphur dioxide or hydrogen sulphide.

§ 2. Nitrogen Monoxide.

Place the ammonium nitrate in the test-tube or Florence flask (*a*), Fig. 7, which is fitted with a perforated rubber stopper and short glass tube, and connected by a rubber tube (*c*) to the quinine bottle (*e*), fitted with a rubber stopper, and one short and one long piece of glass tubing. Fill the bottle (*e*) with water. The gas will pass through (*d*), and force the water up through the tube (*f*).

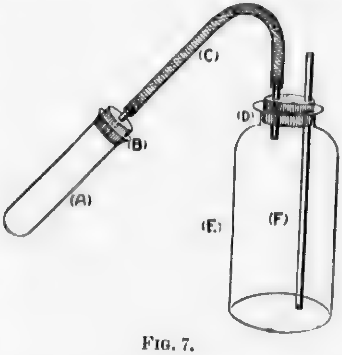

Fig. 7.

If it is desired to wash the gas with ferrous sulphate and caustic potash, test-tubes may be used for wash bottles, and

Fig. 8.

connected as in Fig. 8. When one bottle is full q remove the stopper, cover the bottle with moist mica or and insert the stopper in another bottle full of water many bottles as required may be prepared in this way. reaction ceases, it will be an advantage to remove the st (*b*) from the test-tube, place the thumb over the apertu the stopper and quickly drop it into a bottle of water. will prevent the air from mingling with the prepared A little water may be left in one of the bottles, and sh up with the gas, to show its solubility in cold water. Ob that air bubbles back through the tube (*f*).

§ 3. Nitric Oxide, Carbon Dioxide, Olefiant Gas, etc.

Use apparatus similar to that in Fig. 7. The copper, w water and nitric acid may be placed in the test-tube (*a*), the gas collected in the bottle (*o*), as in the case of nitro monoxide. A little water may be left in one of the bot and shaken up with gas, so that it may be tested with lit paper, both before and after air is allowed to mingle with gas. When a bottle is filled, or when reaction ceases, proc as in the case of nitrogen monoxide. further experiments see any pract text-book. It is best to have a jar Wolff bottle ready, with tube and c attached, as in Fig. 9, so that when flask is disconnected the surplus gas m be passed into the Wolff bottle if t reaction has not ceased. If care taken nitric oxide may be prepared wi out allowing any of the gas to escape into the room.

Fig. 9.

Carbon dioxide, carbon monoxide, marsh gas, olefiant g and acetylene may be handled in the same way. It is som

[tim]es desirable to show how marsh gas and olefiant gas act on chlorine. In the case of marsh gas, it is best to partially fill a bottle or jar with the gas. Then remove the stopper from the generating flask and place in a test-tube in which chlorine is generated, and fill the bottle by forcing out the rest of the water. Quickly attach the generating flask to surplus jar (Fig. 9). In the case of ethylene, it is best to have the olefiant gas and the chlorine prepared in separate bottles, using apparatus Fig. 7.

§ 4. Carbon Monoxide, when Prepared from Oxalic Acid.

When carbon monoxide is prepared from oxalic acid, it is mixed with carbon dioxide. A good method of showing that they are equal in volume is to prepare a quinine bottle full of the gas, as in Fig. 10, and insert a double perforated rubber stopper. Through one aperture pass a funnel (with a stopcock if possible) and through the other aperture pass a short glass tube, and attach with rubber tubing to a wash bottle (test-tube) containing KOH, and then to another quinine bottle filled with water, and arranged as in Fig. 10. Pour mercury into the funnel, and drive the gas slowly through the caustic potash into the second bottle (*b*). Take the precaution to determine the

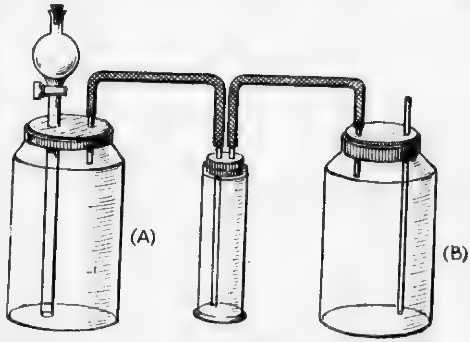

Fig. 10.

volume of the bottles (*a*) and (*b*) when filled with wat
means of a graduate. The quantity of water remaining
may be measured after the gas has been washed, if the b
are not equal in size. A still better method of perfo
this experiment would be to fit up apparatus as describ
the chapter on Gas Analysis.

§ 5. Chlorine, its Preparation and Properties.

In handling this gas it is best to use apparatus Fig. 6.
however, only one bottle is required, it may be prepared
apparatus Fig. 7, and then attach the generating flas
surplus jar Fig. 9, but experience has shown that stud
are not likely to prepare more than one bottle without a
ing the gas to escape when using apparatus Fig. 7. For
reason it becomes a necessity to use apparatus Fig. 6.
experiments with chlorine may be divided into two series.

In the first series of experiments use a test-tube or qui
bottle in place of (*h*) Fig. 6. Fill the large jar (*a*)
water. Prepare the gas by placing manganese dioxide
hydrochloric acid in the test-tube (*k*). Let the gas
through the empty test-tube (*h*), or better, have a little w
in the bottom of the test-tube or bottle, but not enoug
have the gas bubble through it, and permit the surplus ga
pass into the jar (*a*). Quickly remove the test-tube, place
thumb over the mouth, and shake up with the cold wa
and quickly insert a test-tube or bottle full of water in
place, and let the gas bubble through this for some ti
(When showing that the gas is soluble, without removing
thumb invert the test-tube and drop it into a bottle of wat
After the water in the second test-tube is saturated rem
it, and put test-tubes containing solutions of logwood
indigo in its place, to show the bleaching properties of
gas. Into a fourth test-tube place a piece of printed pap

which has been moistened, and on which words are written with lead pencil and ink; let the gas pass over this for some time. Another test-tube might be filled, to show the action of the gas on a piece of blotting paper soaked in turpentine. The chlorine water may now be used to show its action upon the oxides of lead, what happens when it is placed in sunlight and when it is mixed with a solution of sodic hydrate and evaporated.

To prepare some dry gas, use apparatus Fig. 8. Place the sulphuric acid in one test-tube. The dry chlorine will pass into the second test-tube. Into this test-tube put a piece of calico, and let the gas pass over it for some time. Quickly remove the calico, moisten it, and replace in the dry chlorine. If at any time during this experiment the gas ceases to come from the generator, pinch or clamp the rubber tubing between the test-tube and the surplus jar, so as not to allow the gas to become moist, from the water in the receiver. This is very important.

In the second series of experiments use a quinine bottle in place of test-tube (*h*), and force the air into the surplus jar. Quickly remove the bottle when full, cover it with a piece of moist mica or invert it on a sheet of moist paper, and put an empty bottle in its place. Test bottles of the gas prepared in this way, by shaking into it powdered arsenic, and by lowering into it a piece of glowing charcoal and a lighted taper.

Fig. 11.

It cannot be too often impressed upon the student that he must put a test-tube or bottle in the place of (*h*) as soon as it is removed. If this precaution is taken, the gas can be handled without allowing any of it to escape.

To show the action of sunlight upon chlorine water, invert a test-tube full of the solution in an

evaporating dish, or use a tube sealed at one end, similar t Fig. 11. Fill with chlorine water and place in sunligh This experiment, which is recommended in some text-books is more interesting because it illustrates an important prin ciple in physics.

Hydrochloric Acid Gas.—To prepare this gas use apparatu Fig. 6, and as in chlorine, use the test-tube (k) as a generato Fill as many bottles as required, by placing empty bottles i place of (h). To neutralize caustic soda place the solution i the test-tube or bottle (h), and let the gas pass through it fo some time, allowing the surplus gas to pass into the receive

For further experiments see any Practical Chemistry.

Potassic Chloride and Potassic Chlorate.—When prepari KCl and $KClO_3$ use apparatus Fig. 6. Place the hot or co caustic potash in the test-tube (h), and let chlorine gas pa through it as long as desired. It will be observed that th potash may be kept hot while the gas is passing through it.

Bleaching Powder may also be prepared by using the sam apparatus, Fig. 6. Cover the inside of the bottle (h) wit slaked lime, and pass chlorine gas through it as long as nece sary, collecting the surplus gas in the receiver (a).

§ 6. Hydrogen Sulphide, its Preparation and Properties.

The Preparation of the Gas.—It is sometimes difficult prepare hydrogen sulphide quickly and in small quantiti but the chief difficulty, no doubt, arises from the sulphide iron. The following is a simple method which I saw appli recently, for the first time. Take some powdered sulphide iron, and prepare the gas in the ordinary way, or pour so water upon it and let it stand for a time—a few hours, possible. Then pour off the surplus water, just leaving sulphide covered. Now add a few drops of sulphuric ac

and, without heating, the gas instantly comes off. When the action has ceased, pour off the surplus solution, and pour into the test-tube a quantity of clean water, and let it stand until next required. Now pour off the surplus water and add acid. This is an excellent plan where the gas is frequently required and in small quantities. It not only saves the trouble of heating, but always ensures success. It may be necessary to prepare the gas by heating the first time; after that, wash and keep the sulphide covered with clean water, and no trouble will be found.

The Properties of the Gas.—In handling this gas always use apparatus Fig. 6. Prepare the gas in the test-tube (k). Fill the receiver (a) with water, and use test-tubes or quinine bottles in place of (h). Quinine bottles are in many respects better than test-tubes. Into the test-tube (h) place a small quantity of water, but not enough to have the gas bubble through it. Now fill the test-tube with gas, by forcing the gas into the receiver (a). Remove this test-tube, put the thumb over the mouth, and quickly put another test-tube in its place. Shake up the gas in the first test-tube, to show its solubility, and, without removing the thumb, invert the test-tube and drop it into a bottle of water. Dip some pieces of white paper into a solution of lead acetate, and place one of these into another test-tube. Now remove the second test-tube of gas, and put the one containing the paper soaked in acetate in its place. Bring the second test-tube as quickly as possible to the flame of the gas jet. When the hydrogen sulphide ignites place over the burning test-tube a dry quinine bottle, and observe that moisture and sulphur dioxide are formed. Remove the third test-tube and put in its place a test-tube full of water, and let the gas pass through it for a time. Now remove the sulphuretted hydrogen water, and put in its place solutions of copper sulphate, mercuric chloride,

lead acetate, etc. Replace the generating flask with one generating chlorine, and pass some chlorine into the receiver, and through a solution of H_2S. Let a drop of the solution fall on a silver coin, and use some of it to precipitate acid and alkaline solutions of different metals. Some ammonium sulphide might also be prepared by passing the gas through ammonium hydrate. Do not forget to replace one test-tube by another as quickly as possible; upon this will depend your success in handling the gas. Tight-fitting rubber stoppers must be used in these experiments. Never leave the apparatus open for an instant.

§ 7. Sulphur Dioxide: Its Properties.

The same apparatus must be used in handling this gas as in hydrogen sulphide and chlorine (Fig. 6). Use test-tube or quinine bottle in place of (*i*). Fill the receiver (*a*) with water. Heat copper clippings and sulphuric acid in the test-tube (*k*), and proceed as in other gases. Place about half an inch of cold water in the test-tube (*h*), and force the air into the receiver, without allowing the sulphur dioxide to bubble through the water. Quickly remove the test-tube, placing the thumb over the mouth, and put a second test-tube in its place. Shake up the first test-tube, to show the acidity and solubility of the gas. Replace the second test-tube with one containing a highly colored flower. Test for the inflammability of the gas. Remove the third test-tube containing the flower, and put in pure air. Quickly replace this test-tube with solutions of logwood, indigo and potassium permanganate in succession. Now pass the gas through a test-tube full of water, and when it is saturated replace it with an empty test-tube. Test for the properties of sulphurous acid.

This gas is much easier to handle than hydrogen sulphide, and for that reason it is best to study its properties before

attempting to prepare sulphuretted hydrogen. The student needs some practice before studying gases like chlorine and hydrogen sulphide. If only one bottle of sulphur dioxide is required, it may be prepared by using a test-tube and a bottle arranged as in Fig. 7.

Other gases may be studied in the same way. Enough has been given to show the plan.

CHAPTER III.

HINTS ON APPARATUS.

§ 1. Apparatus to Illustrate Combustion.

It is very important to have good experiments to sho that combustion is a chemical action, in which at least tw substances are equally concerned, but the descriptions of suc experiments are not always satisfactory. I have found th following method, which I devised, to work exceptionall well.

For this purpose use Wolff bottles (*a*) and (*c*), Fig. 1 One jar should hold about one and a half or two quarts, an the other about one quart. Fi the necks of the larger jar an one neck of the smaller ja with perforated rubber stopper Through one neck of the large jar (*a*), place a funnel with sto cock (*b*). To the other neck at tach rubber tubing of good lengt and a glass rod eighteen inche long drawn out to a fine point (*d*)

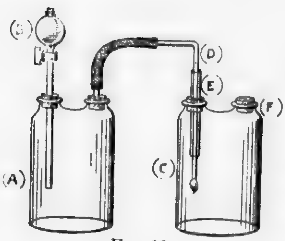

Fig. 12.

Through one neck of the smaller jar place a wide glass tub (*e*)—a part of a medium-sized test-tube does very well. Fi it tightly, by placing around it some adhesive plaster. Thi is to prevent the bottle breaking when the gas is burning.

If you wish to burn oxygen in coal gas, connect the nec (*f*) of the jar (*c*) with the gas supply, and when the air i

driven out, ignite the gas at the tube (*e*). Fill, or partly fill, the Wolff bottle or jar (*a*) by forcing out the water, as in Figs. 6 and 7. Pour water into the funnel (*b*), and force the gas through the tube (*d*). Slowly lower it through the tube (*e*), taking care that it ignites as it is passed down. To reverse the experiment, connect the tube (*d*) with the gas supply, and when ignited lower into the jar of oxygen (*c*).

A much more difficult experiment is to burn chlorine in hydrogen. Arrange the apparatus as in Fig. 13. Fill the jar (*a*) with chlorine by displacing the water, and arrange the funnel (*b*), the rubber tubing and the glass tubing (*d*) as in the figure. Connect the second jar (*c*) by means of a perforated stopper and glass tubing with a Florence flask, in which hydrogen is generated. Invert as in (*c*). When all the air is driven out ignite the hydrogen gas at the mouth of the wide glass tube. Now force the chlorine very slowly out of (*a*)—the smaller the stream of gas the better—and slowly pass it through the wide glass tube in the neck of (*c*), but be careful to see that it ignites. Do not let the chlorine mingle with the hydrogen unless it is ignited. When the gas burns in (*c*) increase the force in the funnel (*b*). It is possible to burn chlorine in the jar (*c*) without having it connected with the flask in which the hydrogen is generated, but it is not satisfactory. Air may be burned in coal gas in the same way, with a little practice. The advantage of this method is that you can regulate the supply.

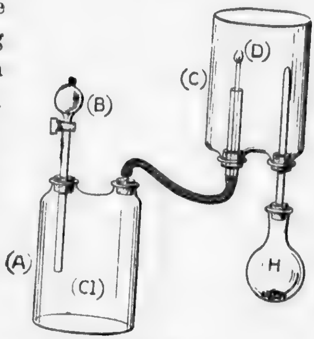

FIG. 13.

§ 2. How to Fill the Eudiometer.

The eudiometer commonly used in our schools consists of straight graduated tube closed at one end, and it is not con venient to pass into it a fixed volume of gas. For exampl if a fixed volume of chlorine has been placed in the eudiom ter, it is not easy to pass into it an equal volume of hydroge In most cases the gas may be passed through the wash bottle and drying tube and into the eudiometer from the flask i

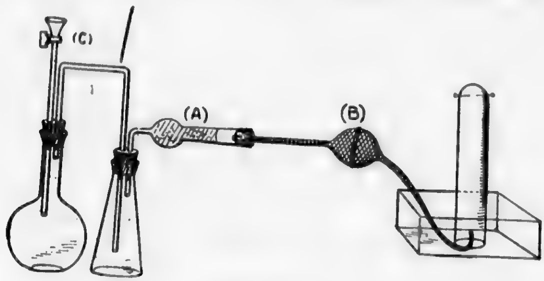

FIG. 14*a*.

which it is generated. Arrange apparatus as in Fig. 14*a*. As in the diagram, attach to the drying tube (*a*) a rubbe tube, in the middle of which is a rubber bulb (*b*), with o without valves, which may be purchased from any druggist. If necessary, attach the other end to the surplus gas jar, and let the gas pass through the apparatus until you are absolutely certain that the tube and bulb are filled with pure dry gas. Then disconnect, and insert a short piece of glass tubing i the end of the rubber tube, and put it into the dish contain ing the eudiometer. Close the stopcock (*c*). When the rubbe bulb is full of gas, press gently, so as to drive out any air i the glass tubing. Then insert the tube under the mouth o the eudiometer, and press on the bulb. Even the smallest volume of gas may be passed into the eudiometer in this way.

This is the case even if the generator has ceased to give off gas. Be careful to see that the stopcock is closed before pressing on the bulb. After forcing out the gas pinch the rubber at the end nearest the eudiometer, so as not to allow the mercury to flow back into the bulb; if the generator has ceased to act, pour water or acid into the funnel, so as to fill the bulb with gas. Even a gas like chlorine may be passed into the eudiometer in this way. When it is desired to repeat the experiment a number of times, fill a quinine or other wide-mouthed bottle (Fig. 14b) with gas. To do this, insert a rubber stopper with three perforations. Through one pass a funnel. Into the second perforation put a long glass tube, reaching nearly to the bottom of the bottle, and into the third place the drying tube, to which is attached the rubber bulb. The long tube may be connected with the generator, and all the air driven out of the apparatus. If this is not satisfactory, fill the bottle with water or mercury. Attach the rubber tube with bulb to the wash bottles of the generator, and force out the liquid through the long tube. Now disconnect the rubber with the bulb from the generator, and insert in the dish containing the eudiometer. Place a short piece of rubber over the long tube, and clamp it. Pour mercury into the funnel, open the stopcock, and let some of it drop into the bottle. When the rubber bulb is full of gas, close the stopcock and insert the tube under the mouth of the eudiometer. Press gently on the bulb. While the hand is still on the bulb, pinch the rubber near the eudiometer, so as not to allow the mercury to flow back; pour more mercury into the funnel, so as to force the gas into the bulb. The reason for using a rubber cork

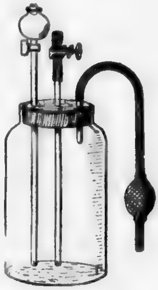

FIG. 14b.

with three perforations is because it is difficult to insert th funnel without allowing air into the bottle after it has bee filled with gas.

When passing air into the eudiometer it might be con venient to have a bulb with valves, but it is not absolutel necessary. Use a drying tube and a rubber tubing with bul Place the finger over one aperture of the drying tube, an force the air out through the other end by pressing on th bulb. Pinch the rubber tubing near the end, and let the ai pass in through the drying tube. If valves are used on th bulb, they may be arranged as in an ordinary atomizer.

§ 3. Apparatus to Illustrate the Decomposition of Water and Hydrochloric Acid.

The apparatus usually sold for the decomposition of wate gets out of repair very easily. Fig. 15 shows a piece o apparatus, designed by the writer, which may be used for th purpose. Take a piece of glass tubing about the size of a test-tube or dryin tube, and have mad as in Fig. 15. Leav tubes (*a*), (*b*), (*c*) an (*d*) open. Have fitte into (*b*) and (*c*) tw uniform test-tubes o equal size which wi slip up and dow easily, without per mitting water to escape when the apparatus is filled. Us pieces of electric-light carbons, about one inch long, for elec trodes, to place in the tubes (*a*) and (*d*). Make a groove i the carbons, to attach the copper wire, and insulate the wir with sealing wax. Have air-tight stoppers, through whic the conductors pass at the opening of the tubes (*a*) and (*d*

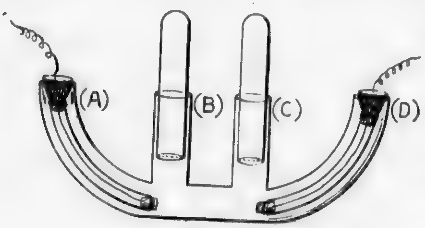

FIG. 15.

When making the gases (in the dark, if necessary) invert the test-tube in (*c*), so that the sealed end will come down nearly to the carbons. Now incline the apparatus, and the mixed gas will pass up (*b*). Attach a drying tube, rubber tubing and bulb (as in Fig. 14*a*), and pass the gases into the eudiometer and explode. Thus it will be seen that the analysis and synthesis of a compound may be shown in one experiment. This cannot be done unless the gases come off in the proper proportions. When decomposing hydrochloric acid, some text-books recommend mixing one volume of concentrated hydrochloric acid with ten volumes of a saturated solution of common salt. This is not satisfactory, unless the current passes through the mixture until it becomes thoroughly saturated with chlorine, which takes considerable time. In most cases it will be found more convenient to prepare the gases separately, and pass into the eudiometer.

The best method of filling the apparatus is to put a stopper in the aperture (*a*), put the test-tubes into place; pour the solution into (*b*), slightly tilting, until completely full. Then slowly slip the electrodes into position, as in the diagram (Fig. 15).

Should the apparatus be used to decompose salts, fuse pieces of platinum, one inch long and half an inch wide, to copper wire, and insulate the wire. Place the platinum tips in the apertures (*a*) and (*d*). This apparatus can be cheaply made by any glass-blower. It prevents leakage, etc.

The apparatus cannot be used without a stand. Figs. 16 and 17 show convenient stands for this purpose. Take two blocks of wood of

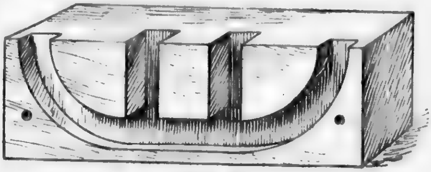

FIG. 16.

similar size, and cut grooves in them, as in the diagram that the apparatus will be held in place when the blocks brought together. They may be held in place by two driven into one side, and holes placed opposite in the o

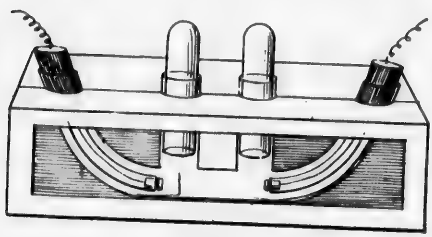

FIG. 17.

The apparatus stand will then the appearance Fig. 17. It wil observed that ap ratus Fig. 15 can used for the dec position of water of hydrochloric a electrolysis of sa and to show there is a back current when disconnected fr the battery and attached to the galvanometer.

§ 4. Apparatus to Illustrate Boyle's Law.

The apparatus now recommended for this experiment to take a tube about 25 cm. in length, and closed with a st cock. Connect this with a rubber tube not less than 50 c long and a glass tube about 50 cm. long. Place on a grad ated support, etc. Take the reading of the barometer.

I have constructed a modified form of this apparatus whi is much easier to make, as it does away with the graduat support. Take a uniform tube sealed at one end, about 30 c long, or use a thistle tube with stopcock. Connect this b means of a heavy rubber tube about 30 inches long with long glass tube about 70 cm. in length. Take narrow stri of paper and graduate with the centimeter scale. Place th strips on the tubes with starch paste or fish glue. Th apparatus will now appear as in Fig. 18.

Wrap the joints firmly with string. As it is necessary t

fill the tube with pure dry air, attach a rubber bulb and drying tube, as in Fig. 14, to the longer tube, and force the dry air through it and the rubber tube until you are sure the apparatus is filled with dry air. Now close the stopcock in (a). If the tube (b) is sealed at the end it will be necessary to fill the longer glass tube and rubber with air before attaching the tube (b). Now fill the tube (b) with mercury and attach the rubber tube. Firmly wrap the joint with a string. Pour some mercury into (a), but in doing so do not allow the air in the room to mingle with the dry air in the tube. Place the tube (b) on the floor. Hold (a) upright and gently raise the tube (b) and then the rubber tube alternately until the required amount of air is in (b). When doing this lift the rubber about the centre. In this way it will be easy to get the required amount of air in (b).

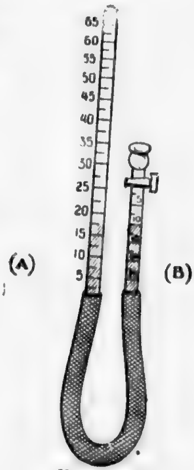

Fig. 18.

Let us suppose we have 10 c.cm. when the mercury is the same level in (a) and (b), and that the barometer stands at 75 cm. Pour about 50 c.cm. into (a). Gradually lower the tube (b) until the volume of the enclosed air is 5 c.cm. The apparatus will now be as in Fig. 19. Mark the level of the mercury in (b) on the rubber tubing at the point (c), Fig. 19. Now raise the tube (b), and with it measure the distance from (c) on the rubber to (o) on the longer tube (a), which we will suppose is 30 cm. This would make the difference of level 75 cm., which should be the same as the barometer.

Now lower the tube (a) as in Fig. 20. Observe the difference in the level of the mercury in (a) and (b) when the

volume is 20 c.cm. This should be 37.5 cm. Use the t
(*a*) as a graduate for measuring the difference in the level.

When made in this way the apparatus need not cost m
than 30 or 40 cents, and can be made
any teacher. I think it is much hand
than with the stand.

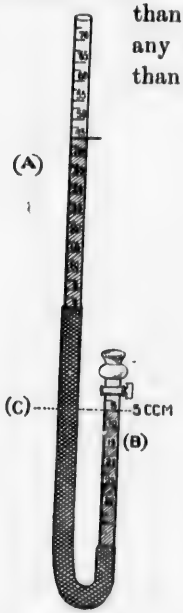

FIG. 19.

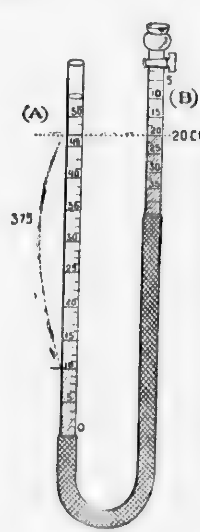

FIG. 20.

§ 5. APPARATUS TO ILLUSTRATE THE LAW OF CHARLES.

For this purpose use apparatus similar to Fig. 19. Th
tube (*b*) need not be graduated and may be much short
Fill the tubes with dry air as in apparatus to illustrate Boyle
law, and pour enough of mercury in (*a*) to bring it above th
level of the rubber. Fit a rubber stopper, with three perfor
tions, in a quinine or other wide-mouthed bottle. Through on
aperture pass the tube (*b*). Through the other perforation

d be 37.5 cm. Use the tul
the difference in the level.
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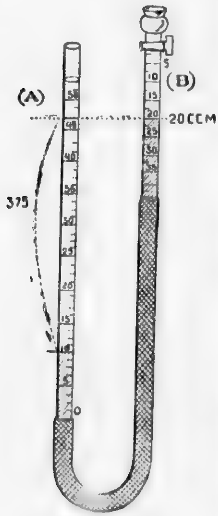

FIG. 20.

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ss short glass rods, one to allow steam to pass in, and the her for the steam to pass out, as in Fig. 21. Place (c) a retort stand and attach (a) to another retort stand. rround (b) with snow and raise (a) until the mercury it is level with that in (b). The gas now under a pressure of one atmos ere. Remove the melting snow by nnecting with a Florence flask of boil- water and pour mercury into (a) raise it if sufficient mercury is already the tube until the mercury in (b) nds at the same level as when the air s surrounded with snow. Observe the ference in the level of the mercury and culate the increase in volume for each gree of increase in temperature. For ample, if the atmospheric pressure was cm. and the tube (a) was raised 25.64 cm., the increase volume would have been $\frac{25.64}{70}$ had the gas been allowed expand without increasing the pressure, because the ume of a gas varies inversely as the pressure.

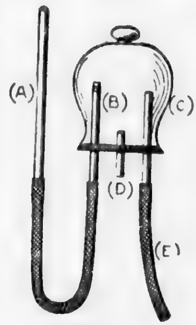

FIG. 21.

NOTE.—If the retort stands are not heavy enough at the se they may be clamped to the table.

§ 6. THE PERCENTAGE OF OXYGEN IN AIR.

In showing the composition of the atmosphere it is often ommended to invert a cylindrical jar over a jet of burning drogen, so that the mouth of the cylinder will be under ter in the dish. This may best be done by filling a jar or olff bottle with hydrogen. (A large bottle with a rubber k with two perforations does very well.) Put the perfor- ed corks with funnel having a stopcock and the connecting ber-tube in place. Pour water into the funnel and force

out the gas and ignite. Having placed the tube in positi lower the cylindrical jar over the jet, Fig. 22. The insta the flame goes out turn the stopcock in the funnel. T will ensure success as the gas can be regulated when burni which cannot be done if comes from a flask when t gas is being generated. If Florence flask is used to ge erate the gas, have in t stopper a funnel with a sto cock. When the gas ju ceases to come off pour wat into the funnel and igni Arrange as in Fig. 22. T gas may then be regulated with a Wolff bottle. It also saves the trouble of filling extra bottle. After the water has ceased to rise in the cyli der, slip a cover glass or mica cover under the jar and tu mouth upwards. The capacity of the cylinder and t amount of water in it may be measured with a graduate.

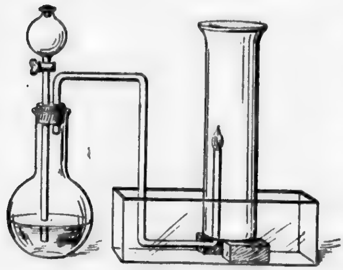

FIG. 22.

§ 7. The Diffusion of Liquids and Gases.

To show the diffusion of liquids through a membrane (osmose) it is sometimes difficult to tie a piece of parchme paper or animal membrane over a funnel or thistle tub This may be conveniently done by tying on the membra as tightly as possible with twine. Then take a piece sealing wax and place it in boiling water until it becom plastic. While in this state remove it from the water a quickly place around the funnel at the point desired, th sealing the membrane to the glass so as to make it reasonab air-tight.

The same difficulty is sometimes experienced in fitting

rforated stopper into a porous battery cell to show the ffusion of gases. It is best to have a rubber stopper for is purpose, but if one cannot be obtained an ordinary cork y be made air-tight with plastic sealing wax, and fitted o the battery cell.

. THE SOLUBILITY OF AIR AND AMMONIA GAS IN WATER.

Ammonia Gas is Soluble in Water.—When working with arge class, the simplest method of illustrating this is to ce some aqua ammonia in a test-tube and over it place inverted empty test-tube. Heat the liquid until the pty tube is full of gas. Remove it, and drop it mouth wnwards into a bottle of water. Have each student do experiment.

Air is Soluble in Water.—In class work one of the best thods is to half fill an evaporating dish or mortar with ter and into it place an inverted test-tube full of water in ich no air is visible. Let the test-tube project over the e of the dish. Gently heat the test-tube above the edge of dish until the water is converted into steam and descends the test-tube. Now take away the lamp and allow the ter to rise. Repeat two or three times and allow the ter to cool. A bubble of air will be found at the top of test-tube.

Surface Tension.—To cause a drop of oil to float in a mixe of alcohol and water, half fill a test-tube with water, put into it one or two drops of oil. Now pour in a little ohol. The drop of oil floats out into the mixture of the e density as itself where its form may be studied. This ometimes used as an illustration of surface tension.

CHAPTER IV.

A SIMPLE METHOD OF GAS ANALYSIS.

PERHAPS the simplest and most complete method of g analysis is the one originated by Prof. Hemphill, but th teacher of chemistry in a secondary school very often do not receive sufficient grant from a school board to purcha the most necessary apparatus, and although there are man times in his work when he would like to determine th different gases in a mixture which comes under his notic he has not the means at his disposal of satisfying h curiosity. If he wishes to overcome the difficulty, he mu either work with inferior apparatus of his own constructio and be satisfied with unsatisfactory results, or he mu purchase rather costly appliances such as Prof. Hemphill at his own expense, and this is something very often h is ill able to afford.

This is the only excuse for submitting the followin simple and original method of gas analysis, as th apparatus employed is such that most teachers have a their disposal, or that can be purchased at a small cos

Take two U tubes used for drying gases with calciu chloride. The shape of the tubes is immaterial, but it woul be convenient to have one of them similar to (*b*) Fig. 2 having the neck between the bulbs narrow so that the ga will not pass through it when being washed. It is best t have the other tube with a stopcock in one arm similar t

ER IV.

F GAS ANALYSIS.

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that used for the analysis of hydrochloric acid, Fig. 1, or of the size and shape recommended for the determination of hydrogen in sulphuric acid, Ex. 7, § 2. One arm of each tube may be drawn out to a point so that the rubber tubing may be slipped over them conveniently. If the arms of the tubes are not drawn out to a point and one of them does not possess a stopcock, they may be connected by rubber stoppers and a short piece of tubing with a clamp placed between them which serves the purpose quite well.

The size of the tubes will depend upon the quantity of gas to be analyzed, but a tube which holds 75 or 80 c.cm. and having stopcocks and graduated as in Fig. 23 would be the most convenient form.

Fill the tube (a) Fig. 23, with the mixture to be analyzed. This may be done by connecting the tube with a generator or gas and letting the gas pass through it until all the air is driven out. Pour water or mercury into the open arm.

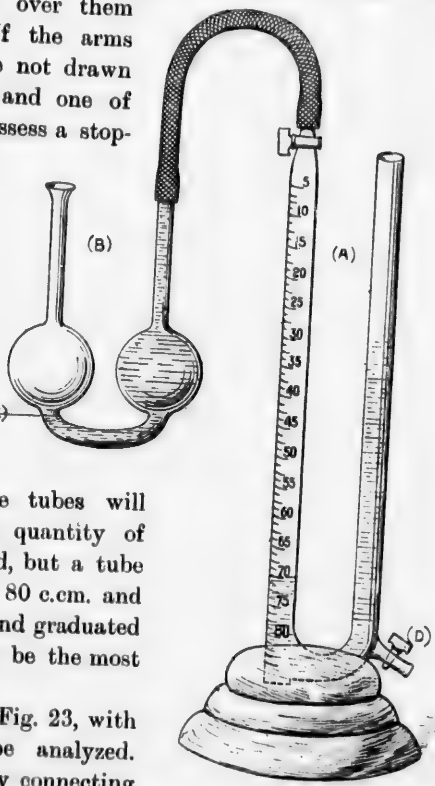

FIG. 23.

Then disconnect from the generator and allow the liquid become level in the two arms and close the stopcock.

Another method would be to close the stopcock and b tilting fill the closed arm with mercury or water so that will rise to the point (*d*) in the open arm. Then conne with the gas jar and open the stopcock. The liquid used w come to a level in both arms. By regulating the quantity liquid with the stopcock or by removing some with a pipet from the open arm, the volume of gas desired will be obtain in the closed arm. Connect the tube (*b*) to (*a*) and by tiltin fill the closed arm with the solution to be used in washin until it reaches the point (*c*) in the open arm. Now open th stopcock and pour liquid into the open arm of (*a*) until all t gas has passed into (*b*). The solution will slowly rise in t open arm of (*b*). If all the gas does not pass over readil remove some of the solution from the open arm of (*b*) with pipette. When the gas is in (*b*), the tube should be lar enough so that the bulb of the closed arm will c ntain so solution. Place the thumb over, or put a rubber stopper in the open arm of (*b*) and by tilting wash the gas thorough Close the stopcock in (*a*) and remove the solution from t open arm until it stands at (*d*).

Now open the stopcock and pour some of the solution us in washing into the open arm of (*b*). By regulating t quantity of liquid in the open arm the gas will pass back in (*a*). If it is desired to accurately determine the volume gas remaining and (*a*) is not graduated, the gas may passed into a graduate and measured, making allowance f the tension of the aqueous vapor, temperature and pressu

The solution for washing the gas may now be removed a another solution put in its place for determining the next g in the mixture.

By having pieces of platinum wire fused into the graduat

tor and allow the liquid
close the stopcock.
close the stopcock and
mercury or water so that
open arm. Then conne
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regulating the quantity
moving some with a pipet
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ube (b) to (a) and by tilti
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oes not pass over readil
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the tube should be lar
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wash the gas thoroughl
ove the solution from t

some of the solution us
(b). By regulating t
the gas will pass back in
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duated, the gas may
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emperature and pressu
may now be removed a
determining the next g

fused into the graduat

be (a), it may be used as a eudiometer to explode marsh s, etc. Eudiometers are sometimes made in this way.

This is not a book on gas analysis and these suggestions e only intended as an aid to those with limited apparatus. ll information on the subject will be found in Hemphill's s Analysis, translated by Dennis and published by Mac- llan & Co.; also, Winkler's Hand-book of Technical Gas nalysis, translated by Lunge and published by John Van oorst, London.

The following may be used in determining the more com- n gases:

A solution of pyrogallate of potash dissolves oxygen.
" " caustic potash " CO_2.
An ammoniacal solution of cuprous chloride dissolves CO d C_2H_2.

Sulphuric acid dissolves ammonia gas.

Ammoniacal solution of silver nitrate dissolves C_2H_2. e gas is also very soluble in water.

Ferrous sulphate (concentrated) dissolves NO.

Cold water or alcohol dissolves N_2O.

Oxygen may also be determined by placing a piece of P in e tube containing the gas and setting the apparatus in the nlight.

Hydrogen is absorbed by palladium asbestos. Some of the bstances may be put into a U tube of fine bore and placed a beaker of water kept at 100° C. while the gas is passing ough the tube. Place this tube between the tubes de- ibed for the analysis of gases, in this chapter, and make e connections with short pieces of rubber tubing. Force e gas slowly backwards and forwards over the palladium bestos three or four times.

Marsh Gas (CH_4) has no absorbent and is determined by nbustion. 100 volumes of incombustible gas are taken for

25 to 37 volumes of methane and oxygen to prevent t[he] combustion of nitrogen.

Ethylene (C_2H_4) is absorbed by bromine water or [by] fuming sulphuric acid. The acid must be so concentrate[d] that when the temperature is lowered crystals of pyrosulphur[ic] acid will separate.

Sulphuretted Hydrogen (H_2S) is determined by le[ad] acetate, also by drawing the gas through iodine water, a[nd] potassium iodide with starch in it. The operation is stoppe[d] as soon as the liquid becomes colorless.

Nitrous Acid (HNO_2) is determined with concentrat[ed] H_2SO_4, or a solution of potassium permanganate acidulat[ed] with H_2SO_4.

Sulphur dioxide (SO_2) is determined with KOH, or [a] solution of iodine.

Bromine, hydrochloric acid and chlorine are also absorb[ed] by KOH.

Nitrogen has no absorbent.

A solution of KOH for testing is usually made by mixi[ng] one part of caustic potash and two parts of water.

An ammoniacal solution of silver nitrate is made by d[is]solving some crystals of silver nitrate in distilled water a[nd] adding just enough aqua ammonia to redissolve the preci[pi]tate formed.

An ammoniacal or acid solution of cuprous chloride may [be] made as follows: Cover the bottom of a bottle of two litre[s] capacity with a layer of copper oxide three eighths of an inc[h] deep. Place in the bottle a number of pieces of rather sto[ut] copper wire reaching from top to bottom. The bundle shoul[d] be one inch in diameter. Fill the bottle with common hydro[-] chloric acid of 1.10 sp. gr. The bottle is occasionally shake[n] and when the solution is colorless or nearly so, it is poured in[to] smaller bottles containing copper wire. Care should be take[n]

that the copper wire does not become entirely dissolved, and that the stopper is greased to keep out the air, as it turns the solution brown and weakens it. To make ammoniacal cuprous chloride, treat the acid chloride with ammonia until a faint odor of ammonia is perceptible. Copper should be kept in it as in the acid solution.

For a number of reasons the alkaline solution is preferable to the acid solution in determining CO.

Pyrogallate of Potash.—Weigh out 5 grams of the solid acid (pyrogallic). Place it in a reagent bottle, and pour upon it 100 c.cm. of potassium hydrate, made as already described.

CHAPTER V.

GENERAL HINTS.

§ 1. Many General Suggestions.

To perforate a rubber stopper, take an ordinary cork bore used for perforating cork stoppers, and heat it in the lamp flame until it becomes quite hot. The stopper may then be easily and quickly perforated. A much better method is to use a solution of caustic potash as a lubricant on the borer.

It is sometimes difficult to attach a piece of rubber tubing to glass tubing. This may be done by wetting the glass tubing with water. The rubber will then slip over the glass quite easily.

When a piece of rubber tubing is larger than the glass tubing it is best to first place a short piece of rubber tubing half an inch long over the glass tubing. The first piece of rubber should be about the same size as the glass tubing. Then place the larger rubber tubing over the smaller piece. This will make the joint quite air-tight.

Adhesive or surgeon's plaster will be found very valuable in the laboratory. It may be used to tighten stoppers in bottles or to make a piece of glass tubing air-tight in a stopper. There are many ways in which it will be found useful in fitting up apparatus, but it cannot be used when heat is applied to the glass vessel.

In filling a narrow glass tube closed at one end with mercury or any other liquid, it will often be found convenient

to connect a thistle tube or funnel to the glass tube by means of a piece of rubber tubing. When the narrow tube becomes clogged with the liquid and the air cannot force its way up, so as to allow the liquid to descend, shove into the tube a bent piece of iron or copper wire of a zigzag outline. The more regular the undulations of the wire the better. Run the wire up and down quickly a few times. The liquid will descend quite rapidly and the tube may be filled in a short space of time.

Most noxious gases, such as carbon dioxide, freely dissolve in cold water. That is why a room which is much occupied, such as a school-room or a bedroom, may be almost completely aerated by having a pail of cold water left in it over night. For the same reason the apparatus described in another chapter for handling noxious gases may be constantly used without having any gas escape.

To toughen glassware, lamp chimneys, etc., immerse them in cold water to which some common salt has been added. Boil the water well and cool slowly. Glass treated in this way will resist any sudden change of temperature.

A burette or bottle, which is wet with water, may be dried by rinsing with alcohol, and then with ether, and blowing a current of air through or into it. Sometimes alcohol is all that is necessary if the glass is allowed to stand for a few minutes after rinsing.

Sealing wax may be made plastic by placing it in boiling water. When in this state it may be used for many purposes in fitting up apparatus and making it air-tight.

§ 2. Cements.

Cement Proof Against Acids.—Take some India rubber and melt it. Add about 6 or 8 per cent. by weight of acid and keep stirred. Next day add lime until it becomes a soft

paste and, lastly, add enough red lead to make it dry an harden.

A Fire-proof Cement for China and Glassware.—Into thick solution of gum arabic stir plaster-of-Paris until becomes the consistency of cream. Apply with a brush t both edges. In about three days it cannot be broken. Th cement is very white.

§ 3. To Remove Stains.

The teacher of science is so frequently asked for metho of removing stains from clothing that the following whic have been collected from various sources are given here.

Silver nitrate stains may be removed from the hands from goods by washing in a strong solution of potassiu iodide or ammonia. Potassium cyanide is sometimes use but it is a violent poison and its use is attended with dange

The most obstinate stains of iodine may be removed b soaking them for some time in cold water and then soakin them over night in starch paste and rubbed. They may als be removed by a strong solution of sodium bicarbonate.

Stains caused by sulphuric acid and hydrochloric acid ma be removed by treating them with dilute ammonia or bica bonate of soda to neutralize the acid, and then sponge wit chloroform to restore the color. This will not do for nitri acid. Ammonia or bicarbonate of soda sets the stain. Whe nitric acid falls on cloth thoroughly sponge it, as quickly possible, with water and then with a little chloroform. If nitric acid stain is already formed there seems to be no wa of restoring the color.

Cream of Tartar and alcohol will remove grass stains fro the daintiest goods, as it never stains the most delicate shad

A strong solution of borax will remove oil stains fro cotton and linen.

Boiling water poured through a cloth for some time will remove tea stains, cherry and many other fruit stains. If this does not succeed, turpentine will remove obstinate stains.

Stains of iron rust may be removed by placing on them first some common salt and then some lemon juice. Wash at once with cold water.

Ink, fruit and mildew stains may be removed by putting them first in cold water and then in half a pint of water to which a teaspoonful of lemon juice and half a teaspoonful of oxalic acid have been added. Afterwards wash with clear water.

Sulphurous acid will whiten undyed goods, straw, etc.

Goods dyed with aniline dyes and faded from exposure to the sun should be sponged with chloroform.